

SPECIFICATION

TO ALL WHOM IT MAY CONCERN:

BE IT KNOWN THAT WE, Kazuhisa Tsunoi, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Hidehiko Kira, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Shunji Baba, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Akira Fujii, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Toshihiro Kusagaya, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Kenji Kobae, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Norio Kainuma, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan, Naoki Ishikawa, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan and Satoshi Emoto, a citizen of Japan residing at Kawasaki-shi, Kanagawa, Japan have invented certain new and useful improvements in

MOUNTING METHOD OF SEMICONDUCTOR DEVICE

of which the following is a specification : -

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MOUNTING METHOD OF SEMICONDUCTOR DEVICE

BACKGROUND OF THE INVENTION

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The present invention generally relates to a mounting method of a semiconductor device, and more particularly to a method of mounting a semiconductor device on a board in accordance with a COB (Chip On Board) method.

(2) Description of the Related Art

V various methods have been proposed as the COB (Chip On Board) method of mounting a semiconductor device on a board, based on purposes and uses of the semiconductor device. A flip-chip mounting method is one of the methods proposed as the COB method. In this mounting method, a semiconductor device (a semiconductor chip) is directly mounted on a board without wires connecting the semiconductor device to the board. The flip-chip mounting method is also called a wireless bonding mounting method.

A description will be given, with reference to Figs. 1A through 1F, of the flip-chip mounting method.

25 Pads 2, which are electrodes, are formed on
a chip 1 (the semiconductor device) to be mounted on a
board 3. Pads 4 which are parts of conductive wiring
patterns are formed on the board 3 on which the chip 1
is to be mounted.

30 First, bumps are formed as shown in Fig. 1A. Referring to Fig. 1A, an end portion of a gold wire 5 is pressed on a pad 2 of the chip 1 and heated by a bonding tool so as to be joined to the pad 2. In this state, the gold wire 5 is then removed. As a result, 35 a tear-drop shaped bump 6 is formed on the pad 2. On all the pads 2 of the chip 1, tear-drop shaped bumps 6 are formed in the same manner as that describe above.

1 Next, the tear-drop shaped bumps 6 are
flattened as shown in Fig. 1B. Referring to Fig. 1B,
the tear-drop shaped bumps 6 are pressed on a flat
plate 7 so that only a point end portion of each of
5 the tear-drop shaped bumps 6 is subjected to the
plastic deformation. As a result, the tear-drop
shaped bumps 6 are shaped into bumps 6 having
substantially the same height.

 Conductive paste is then transferred to a
10 surface of each of the bumps 6 as shown in Figs. 1C
and 1D. That is, the end portions of the bumps 6 are
immersed in a layer of conductive paste 8 as shown in
Fig. 1C and then pulled up therefrom as shown in Fig.
1D. As a result, a drop of the conductive paste 8 is
15 adhered to the end portion of each of the bumps 6.
The conductive paste 8 is made, for example, of epoxy
resin in which a large amount of silver fillers are
distributed. Due to the drop of the conductive paste
8, positive electrical conductivity can be maintained
20 between each of the bumps 6 of the chip 1 and a
corresponding one of the pads 4 of the board 3 when
the chip 1 is mounted on the board 3.

 Next, adhesive 9 is applied to or printed on
the surface of the board 3 so that the pads 4 are
25 covered with the adhesive 9 as shown in Fig. 1E. A
thermosetting insulating adhesive, made of material
including epoxy resin as the principal ingredient, is
used as the adhesive 9 to be applied to the board 3.
In a state where the chip 1 is mounted on the board 3,
30 the space between the chip 1 and the board is filled
with the adhesive 9. As a result, the chip 1 and the
board 3 are tightly joined to each other. In
addition, a connecting portion in which each of the
bumps 6 are joined to a corresponding one of the pads
35 4 is covered with the adhesive 9, so that moisture is
prevented from entering the connection portion by the
adhesive 9.

1 Finally, the chip 1 is mounted on the board
3 as shown in Fig. 1F. Referring to Fig. 1F, the chip
1 is positioned so that each of the bumps 6 of the
chip 1 corresponds to one of the pads 4 of the board
5 3. A thermopressing head then presses the chip 1 on
the board 3, so that each of the bumps 6 is pressed on
a corresponding one of the pads 4 of the board 3. The
adhesive 9 and the conductive paste 8 are thus
hardened by the heat, so that the chip 1 is completely
10 mounted on the board 3.

The board on which semiconductor devices are
mounted is set and used in electronic equipment, such
as a personal computer. Due to the heat generated by
the semiconductor devices on the board, the interior
15 of such electronic equipment is at a high temperature.
Particularly, in a case where a processor operated at
a high frequency is included in the semiconductor
device, a large amount of heat is generated. On the
other hand, in a case where the electronic equipment
20 is not used, that is, a power supply of the electronic
equipment is in an off-state, the interior temperature
of the electronic equipment decreases to a room
temperature.

The interior temperature variation of the
25 electronic equipment affects the connecting portion in
which each of the semiconductor devices and the board
are connected to each other as follows.

As shown in Fig. 2, due to the temperature
variation, the adhesive 9 between the semiconductor
30 device 1 (the chip) and the board 3 is thermally
expanded and contracted, so that the volume of the
adhesive 9 is varies. Of course, thermal expansion
and contraction occurs in the board 3, the
semiconductor device 1 and the bumps 6. However the
35 rate of expansion (contraction) thereof is less than
that of expansion of the adhesive 9. Thus, in a case
where the temperature is increased, the volume of the

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1 adhesive 9 is increased and the increase of the volume
of the adhesive 9 functions as a force to increase the
distance between the board 3 and the semiconductor
device. As a result, a contact force of the bumps 6
5 to the pads 4 of the board 3 is decreased, so that an
electric contact resistance between each of the bumps
6 and a corresponding one of the pads 4 is increased.

Further, when the temperature is repeatedly
increased and decreased, the electrical contact
10 resistance is successively increased and finally a
disconnection may occur between the bumps 6 and the
pads 4.

SUMMARY OF THE INVENTION

15 Accordingly, a general object of the present
invention is to provide a novel and useful mounting
method of a semiconductor device in which the
disadvantages of the aforementioned prior art are
eliminated.

20 A specific object of the present invention
is to provide a method of mounting a semiconductor
device on a board so that even if the volume of
adhesive between the semiconductor device and the
board is varied by the variation of temperature, an
25 increase of the electrical contact resistance of the
semiconductor device to the board can be prevented.

The above objects of the present invention
are achieved by a method of mounting a semiconductor
device including bumps, on a board having pads, so
30 that each of said bumps is joined to a corresponding
one of said pads, an adhesive to be hardened by heat
being provided between said semiconductor device and
said board, said method comprising the steps of:
pressing said bumps of said semiconductor device on
35 said pads of said board; and heating a portion in
which each of said bumps and a corresponding one of
said pads is in contact with each other, wherein a

1 pressure of said bumps to said pads reaches a
predetermined value before a temperature of said
adhesive to which heat is supplied in step (b) reaches
a hardening temperature at which said adhesive is
5 hardened.

According to the present invention, since
the bumps are pressed on the pads with a pressing
force of a predetermined value before the adhesive is
completely hardened, the bumps can be securely joined
10 to the pads so as to provide a sufficient contact
area. Thus, even if the hardened adhesive is expanded
and contracted by the variation of temperature, the
electrical contact between the bumps and the pads can
be maintained.

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BRIEF DESCRIPTION OF THE DRAWINGS

Other objects, features and advantages of
the present invention will be apparent from the
following description when read in conjunction with
20 the accompanying drawings, in which:

Figs. 1A through 1F are diagrams
illustrating a procedure of mounting a semiconductor
device on a board;

Fig. 2 is a cross sectional view showing a
25 connecting portion in which the semiconductor device
and the board are connected to each other;

Fig. 3 is a diagram illustrating a
relationship between the board and the semiconductor
device supported by a head used in a thermopressing
30 step;

Fig. 4 is a timing chart illustrating a
variation of contact pressure of a bump to a pad and a
variation of adhering temperature;

Fig. 5 is a characteristic diagram
35 illustrating a variation of contact resistance to
a variation of contact pressure between gold (Au) and
copper (Cu);

1 Fig. 6 is a diagram illustrating an example
of a chip mounting machine;

 Fig. 7 is a diagram illustrating a polyimide
film set between the head and the chip in the
5 thermopressing step; and

 Fig. 8 is a diagram illustrating a variation
of a pressing force of the head to the chip and a
variation of the temperature of the adhesive.

10 DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

 A description will be given, with reference
to Figs. 3 through 5, of a mounting method according
to an embodiment of the present invention.

 Referring to Fig. 3, a chip 31 (the
15 semiconductor device to be mounted) is supported by a
thermopressing head 30. The chip 31 is mounted on a
board 33 by an operation of the thermopressing head
30.

 The thermopressing head 30 is movable in
20 directions indicated by arrows in Fig. 3 and provided
with a heater 301 and a vacuum cavity 302. The heater
301 is supplied with an electric current from a power
supply. The heater 301 generates an amount of heat
sufficient to warm up adhesive 39 (which will be
25 described later) to a temperature needed to harden the
adhesive 39. The vacuum cavity 302 is connected to a
vacuum system (not shown) so as to support the chip 31
by a suction force of the vacuum.

 A bump 36 made of gold (Au) is formed on a
30 pad 32 of the chip 31. The bump 36 has a bowl-shaped
root portion and an end portion.

 An end of a gold wire is pressed on the pad
32 and heated by a bonding tool so as to be joined to
the pad. The gold wire is then removed. As a result,
35 the bump 36 having a tear-drop shape is formed on the
chip 31. The point end portion of the tear-drop
shaped bump 36 is flattened. Conductive paste 38 is

1 then transferred to or printed on the surface of the
flattened end portion of the bump 36. The conductive
paste 38 is made of a thermosetting resin, such as the
epoxy resin, in which silver (Ag) fillers are
5 distributed. The conductive paste 38 transferred to
the flattened end portion of the bump 36 is preheated
so as to be in a semi-hardened state.

The surface of the chip 31 opposite to the
surface on which a circuit is formed is held in
10 position by the vacuum cavity 301, so that the chip 31
is supported by the thermopressing head 30.

The board 33 is positioned and fixed on a
table 40. A pad 34 which should be electrically
connected to the bump 36 is formed on the board 33.
15 The pad 34 is generally made of copper (Cu).

The adhesive 39 is applied to the surface of
the board by using a dispenser or a printing
technique. The adhesive 39 is made of thermosetting
insulating resin including epoxy resin as the
20 principal ingredient. The adhesive 39 has a heating
characteristic by which liquidity of the adhesive is
produced by an initial heating stage and then is
gradually hardened with increasing temperature. Thus,
since liquidity of the adhesive 39 applied to the
25 whole surface of the board 33 is temporarily produced
when the chip 32 is pressed on the board 33 by the
thermopressing head 30, the adhesive 39 is prevented
from flowing between the bump 36 of the chip 32 and
the pad 34 of the board 33. The adhesive 39 may be
30 applied to the surface of the board 33, except for the
pad 34, by using the printing technique.

Fig. 4 is a timing chart indicating a time
variation of the temperature and pressure in a
thermopressing step. In Fig. 4, the axis of the
35 abscissa indicates the time t and the axis of ordinate
indicates the temperature T and the pressure P .

In a state where the chip 32 is set in the

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1 thermopressing head 30, the thermopressing head 30
start to go down toward the table 40. The chip 32 is
pressed on the board 33 by the thermopressing head 30.
While the thermopressing head 30 is going down, the
5 contact pressure PP of the bump 36 of the chip 32 to
the pad 34 of the board is gradually increased from a
time t_0 .

In addition, the temperature TT of the
adhesive 39 is gradually increased from room
10 temperature RT. The reason is that the thermopressing
head 30 is preheated by the heater 301 at a
temperature sufficient to harden the adhesive 39.

While the temperature TT of the adhesive 39
is gradually increased, liquidity of the adhesive 39
15 is temporarily produced, that is, the viscosity of the
adhesive is decreased. Thus, the adhesive 39 applied
to the surface of the pad 34 is eliminated by the bump
36 being pressed on the pad 34. As a result, the
adhesive 39 will not be present between the bump 36
20 and the pad 34.

While the thermopressing head 30 is moving
further down, the contact pressure PP and the
temperature TT of the adhesive 39 are increased. The
thermopressing head 30 stops movement at a time t_1 and
25 is maintained at the position. At this time (t_1), the
contact pressure PP of the bump 36 to the pad 34 is
maintained at a value PA shown in Fig. 5.

Fig. 5 shows a relationship between the
contact pressure P and the electrical contact
30 resistance R between the gold (Au) and the copper
(Cu). In a region in which the contact pressure P is
small, the electrical contact resistance is large.
This region means that the connection between the gold
and the copper is inferior. When the contact pressure
35 P is increased and reaches a value equal to or greater
than P_1 , the electrical contact resistance rapidly
decreases. This state means that the connection

1 between the gold and the copper is favorable.

The value PA at which the contact pressure PP of the bump 36 to the pad 34 should be controlled is set so as to be greater than the value P1. For
5 example, it is preferable that the value PA is set at 30 grams. The value PA of the contact pressure PP is a value sufficient to provide plastic deformation to not only the end portion of the bump 36 but also the root portion of the bump 36. In addition, due to the
10 contact pressure PP at the value PA, the pad 34 of the board 33 is subjected to plastic deformation by the bump 36.

At the time t_1 , the temperature TT of the adhesive 39 does not reach a hardening temperature HT
15 at which the adhesive 39 should be hardened. At a time t_3 , the adhesive 39 starts to be heated at the hardening temperature HT. Until the time t_3 , the adhesive 39 is gradually hardened. From the time t_3 , the adhesive 39 is heated at the hardening temperature
20 HT so as to be rapidly hardened. A time needed to completely harden the adhesive 39 depends on ingredients of the adhesive 39 and is, for example, within a range between 15 seconds and 20 seconds.

Until the adhesive 39 is completely
25 hardened, the thermopressing head 30 maintains the bump 36 in a state in which it is pressed on the pad 34 with a contact pressure PP of the value PA. At a time t_4 , after the adhesive 39 is completely hardened, the vacuum cavity 302 of the thermopressing head 30 is
30 returned to atmospheric pressure so that the chip 32 is released from being supported by the thermopressing head 30. The thermopressing head 30 then starts to go up. Since the adhesive 39 is released from being heated by the thermopressing head 30, the temperature
35 of the adhesive 39 is gradually decreased to the room temperature RT.

With decreasing of the temperature, the

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1 volume of the adhesive 39 is decreased, that is, the
adhesive 39 is contracted. Thus, it is expected that
the contact pressure is temporarily decreased
immediately after the head 30 goes up and is separated
5 from the chip 31. However, due to the contraction of
the adhesive based on the decreasing temperature, a
tension force is generated between the chip 31 and the
board 33. As a result, the pressure force of the bump
36 to the pad 34 returns to and can be maintained at
10 the initial value PA.

Thus, in a state where the chip 31 is used
inside electronic equipment, even if the adhesive 39
is expanded and contracted based on the variation of
the temperature, a decrease of the contact pressure of
15 the bump 36 to the pad 34 can be limited to a minimum
value. As a result, the reliability of the electrical
connection of the chip 1 with the board 33 can be
maintained.

The thermopressing head 30 from which the
20 chip 32 has been separated is maintained at the
hardening temperature of the adhesive. In the
manufacturing process, the next chip is then supported
on the thermopressing head 30 by the vacuum suction
force.

25 [MODIFICATIONS OF THE EMBODIMENT]

In the above embodiment, the conductive
paste 38 covering the surface of the bump 36 is made
of resin in which silver fillers are distributed.
However, the conductive paste 38 may be made of
30 anisotropic conductive adhesive in which capsules are
distributed, each of the capsules being formed by
covering silver articles with resin. In this case,
the cover of each of the capsules is broken when the
bump is pressed on the pad. The silver articles being
35 positioned between the bump and the pad.

In addition, the electrical connection
between the bump 36 and the pad mainly depends on the

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35 The transferring mechanism 53 has reel
supporting blocks 70 and 71 installed at both sides of
the gate-shaped block 51, reels 72 and 73 rotatably

1 supported by the reel supporting blocks 70 and 71,
motors 74 and 75 rotating the reels 73 and 74, and a
polyimide film sheet 76. The polyimide film sheet 76
is wound on the reels 72 and 73 from both sides
5 thereof so as to cross the gate-shaped block 51. A
stainless steel plate 80 which is used as a jig is
transferred by a conveyer and set on the table 40A.
The polyimide film sheet 76 is located at a position
(H1) slightly higher than the stainless steel plate 80
10 set on the table 40A. The polyimide film sheet 76 is
transferred in a direction A by rotation of each of
the reels 72 and 73 respectively driven by the motors
74 and 75.

The polyimide film sheet 76 has a relatively
15 low thermal conductivity, such as 12 °C/cm. The
thickness of the polyimide film sheet 76 is 25 μm. A
heater 95 is mounted in the table 40A, so that the
table 40A is heated at 80°C.

The raising and lowering mechanism 52 causes
20 a guide 55 of a head supporting mechanism 54 to go up
and down (vertically reciprocate).

A description will now be given of the chip
mounting method using the chip mounting machine 50
having the structure as described above.

25 First, the chip 10 is provisionally mounted
on a flexible printed circuit board 81 which is fixed
on the stainless steel plate 80, using a chip
provisional mounting machine (not shown). As a
result, a semi-finished product 90 in which the chip
30 10 is provisionally mounted is formed. Next, the
semi-finished product 90 is transferred to the chip
mounting machine 50 by the conveyer and set therein.
The head 30A presses the chip 10 on the flexible
printed circuit board 81, with heat, so that the chip
35 10 is completely mounted on the flexible printed
circuit board 81.

Fig. 6 shows a state in which the semi-

1 finished product 90 transferred into the chip mounting
machine 50 is positioned and set on the table 40A.
The polyimide film sheet 76 is slightly over the chip
10.

5 After it is recognized that the semi-
finished product 90 is positioned and set on the table
40A, the raising and lowering mechanism 52 is operated
so that the head 30A moves downwardly. As enlarged
and shown in Fig. 7, the head 30A presses the chip 10
10 on the flexible circuit board 81 with application of
heat. Between the head 30A and the chip 10, the
polyimide film sheet 76 is set. After a predetermined
time has elapsed, the head 30A is caused to move
upwardly and separate from the chip 10.

15 When the raise and fall mechanism 50 is
operated so that the head supporting mechanism 54
moves downwardly and the head 30A is brought into
contact with the chip 10, a spring 56 starts to be
compressed. After this, the pressure of the head 30A
20 to the chip 10 is increased by increasing the amount
of compression of the spring 56. The raising and
lowering mechanism 50 is operated until the amount of
compression of the spring 56 reaches a predetermined
value. An initial amount of compression of the spring
25 56 is adjusted by a screw 57.

The pressing characteristic of the head 30A
pressing the chip 10 is indicated by a line I in Fig.
8. That is, the pressure of the head 30A to the chip
10 is gradually increased starting from a time t_{10} as
30 indicated by a line Ia and reaches a value PAa at a
time t_{12} . After this, the pressure is maintained at
the value PAa as indicated by a line Ib and is
gradually decreased starting from a time t_{14} as
indicated by a line Ic. The time t_{14} is a time at
35 which a time period T1 that is needed to completely
harden the adhesive 39 elapses from a time t_{13} at
which the temperature of the adhesive 39 reaches the

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1 hardening temperature of 170°C.

 In addition, starting from a time at which
the head 30A is brought into contact with the chip 10,
the adhesive 39 is heated via the chip 10 until the
5 temperature of the adhesive 39 reaches the hardening
temperature of 170°C. The temperature of the adhesive
39 varies as indicated by a line II in Fig. 8.

 If the polyimide film sheet 76 is not set
between the head 30A and the chip 10 so that the head
10 30A is in direct contact with the chip 10, the
temperature of the adhesive 39 is rapidly increased as
indicated by a line IIa in Fig. 8. A time period T2
between the time t_{10} at which the head 30A is brought
into contact with the chip 10 and a time t_{11} at which
15 the temperature of the adhesive 39 reaches the
hardening temperature of 170°C is relatively short.
As a result, the time t_{12} at which the pressure of the
head 30A to the chip 10 reaches the predetermined
value PAa is after the time t_{11} . That is, before the
20 pressure of the head 30A to the chip 10 reaches the
predetermined value PAa, the adhesive starts to be
hardened. Thus, some of the bumps 36 may be
incompletely joined to the pads.

 On the other hand, according to the above
25 method of the present invention, since the polyimide
film sheet 76 is set between the head 30A and the chip
10, the heat is transmitted through the polyimide film
sheet 76 having a low thermal conductivity to the
adhesive 39. As a result, the temperature of the
30 adhesive 39 is increased, starting from the time t_{10}
at which the head 30A starts to press the chip 10, to
the hardening temperature of 170°C as indicated by a
line IIb. The line IIb is more gently sloping than
the line IIa. A time period T3 between the time t_{10}
35 at which the head 30A starts to press the chip 10 and
the time t_{13} at which the temperature of the adhesive
39 reaches the hardening temperature of 170°C is

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1 greater than the time period T2 described above by T4.

Thus, the pressure of the head 30A to the
chip 10 reaches the predetermined value PAa at the
time t_{12} , before the time t_{13} . That is, before the
5 adhesive 30 starts to be hardened, the pressure of the
head 30A to the chip 10 reaches the predetermined
value PAa. After the pressure reaches the
predetermined value, the adhesive 39 starts to harden.
As a result, the bump 36 is appropriately pressed on
10 the pad so as to be securely joined to the pad. Thus,
the chip 10 can be mounted on the board with a high
reliability.

In addition, in Fig. 8, a line IIc indicates
an increasing characteristic of the temperature of the
15 adhesive 39 when the semi-finished product 90 is set
on and heated by the table 40A.

Since the polyimide film sheet 76 has a heat
resistance property, the polyimide film sheet 76 does
not adhere to the head 30A and chip 10. The polyimide
20 film sheet 76 is flexible, so that the surface of the
chip 10 is not damaged.

After the head 10A moves upwardly and is
separated from the chip 10, the motors 73 and 74 are
driven so that the polyimide film sheet 76 is moved by
25 one step. As a result, a part of the polyimide film
sheet 76 which was set between the head 30A and the
chip 10 is moved to the outside of the gate-shaped
block 51 and a new part of the polyimide film sheet 76
which has not yet been used is fed into a space in the
30 gate-shaped block 51. The new part of the polyimide
film sheet 76 is used for the next semi-finished
product 90 so as to be set between the head 30A and
the chip 10.

A polyester film sheet or a silicon film
35 sheet may be substituted for the polyimide film sheet
76.

Instead of setting material having a low

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1 thermal conductivity, such as the polyimide film sheet
76, between the head 30A and the chip 10, the head 30A
may be temporarily cooled immediately before the head
30A is brought into contact with the chip 10.

5 If the heater in the head 30A is turned on
after the head 30 presses the chip 10, the adhesive 39
can start to be hardened after the pressure of the
head 30A to the chip 10 reaches the predetermined
value PAa without the polyimide film sheet 76.

10 However, according to this method, a time period
required for mounting the chip is increased, so that
production deteriorates. From a viewpoint of
production, the method according to the above
embodiment of the present invention is preferable.

15 The present invention is not limited to the
aforementioned embodiments, and other variations and
modifications may be made without departing from the
scope of the claimed invention.

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